

High Resolution Stereo Imaging System for Sediment Roughness Characterization

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LONG-TERM GOALS

To develop and apply a high-resolution digital stereo photography system to characterize multiple scales of seafloor roughness.

OBJECTIVES

The scientific objective is to characterize the temporal and spatial variability of seafloor roughness at spatial scales ranging from sub-millimeter (sand grain size) to tens of centimeters (small sand ripple size).

APPROACH

A high-resolution stereo imaging system was developed and deployed during the Sediment Acoustics Experiment 2004 (SAX04). In order to address the issue of spatial variability, the APL-UW stereo camera system was designed to be a light, self-contained system that could be easily and rapidly moved to multiple positions at the experiment site. The system frame consists of a tripod and an aluminum frame to which a computer, two cameras, a strobe, and an altimeter are mounted (see Fig. 1). At the center of the frame is the main pressure case which houses a PC-104 computer. The computer triggers the strobe and cameras, and stores images captured by the cameras for subsequent processing. The computer also has an attitude sensor for measuring the orientation of the camera system at each capture.

Along one leg of the frame are two smaller pressure cases which house digital cameras. The cameras are Basler A102f digital cameras which have 1300x900 pixel resolution. Higher resolution digital cameras are available, especially in consumer SLR models, but the decision was made to use an industrial camera since this provides the most flexibility in the choice of optics and the most direct computer control of the camera. By using these cameras, it was possible to trigger the strobe and the image capture on both cameras simultaneously. This provides both rapid image acquisition and

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allows for image acquisition when the frame is in motion such as when there is strong swell on the bottom or when the system is suspended above the bottom.

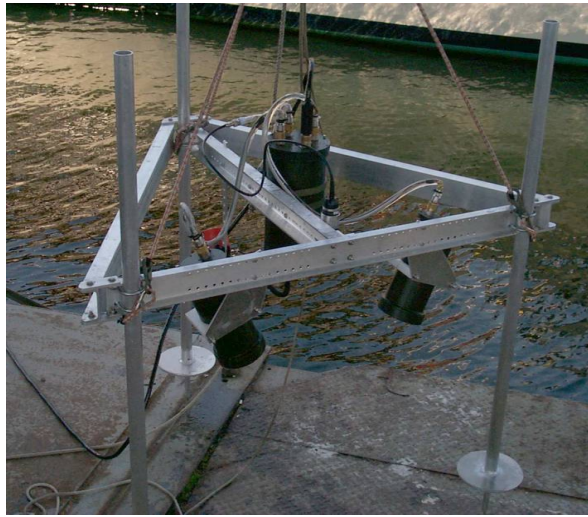


Figure 1. APL-UW Stereo camera system.

The capture rate for the system is roughly 20 stereo pairs per minute. Both the height of the cameras from the bottom and the separation and tilt of the cameras can be changed depending on the measurement to be performed. The camera separation can be varied from 10 to 60 cm and the height of the cameras can be varied from 10 to 80 cm from the bottom. The primary light source used with this system is an Ikelite DS-125 substrobe which is battery powered. The system can also use an acoustic altimeter to measure the height of the system above the bottom and trigger the image capture when a preset height is reached.

The system is connected to the ship with 100 m of cable for both power and communication with the ship via Ethernet. For operation at SAX04, the frame was lowered from the ship to the seafloor and then moved to the area where measurements were to be made. Typically the system was set in a mode to capture 10 images, taken at 3-second intervals, at a single position followed by a longer 15-second interval in which two divers would move the system to a new position. Multiple images at a single position allows for averaging or other processing to remove the effects of particulate matter suspended in the water column or moving along the bottom.

WORK COMPLETED

The performance of the system was evaluated using a machined surface with a known roughness spectrum (developed in conjunction with C.C. Wang at the Institute of Undersea Technology at National Sun Yat-sen University in Taiwan.) The use of the machined surface confirmed the accuracy of the stereo camera system and the techniques developed to process the stereo images. It also indicated that the limitations of our system, specifically the presence of a noise floor at -35 dB cm^3 for the configuration of the stereo system as deployed during SAX04.

In October 2004, the stereo camera was deployed at the SAX04 experiment site. The SAX04 deployment began in late September and lasted until early November [1]. Just prior to deployment, Hurricane Ivan made landfall at Gulf Shores, AL, approximately 100 miles west of the experiment site, with the brunt of the hurricane hitting the site itself. This had significant implications for the experiment in that the resulting storm surge and waves pulled mud and other materials from shore. This created a mud layer above the sand at the experiment site and greatly increased the turbidity reducing visibility at times to less than one foot. This made it very difficult to deploy the acoustical experiments and made it impossible to make any optically-based measurements for the first half of the experiment. It was not possible to make any useful stereo camera measurements until mid-October, more than halfway through the experiment.

Despite these difficulties, the APL-UW stereo camera system was deployed to four separate locations at the SAX04 site and captured multiple stereo pairs at those locations. The images captured at two of these locations could be processed. The first set was captured along a line north of the APL-UW rail system [2] and the second set was captured along a line south of the SAS rail system in the SAS target field. The power spectra obtained from these images have been compared to IMP2 data taken in nearby locations and at roughly the same time.

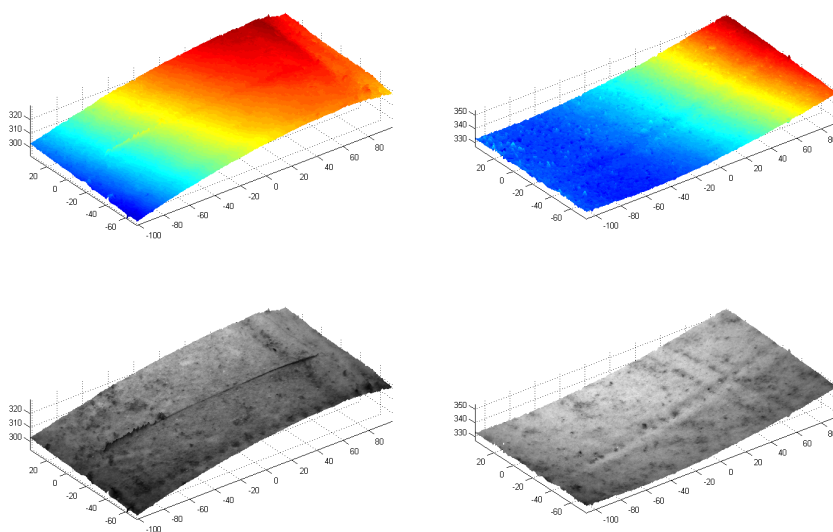


Figure 2: Examples of surface roughness measurements in the NSWC-PC test pond after a ripple has been scraped into the sand bottom. The features running along the long axis of the surfaces were produced by the IMP2 measurement system.

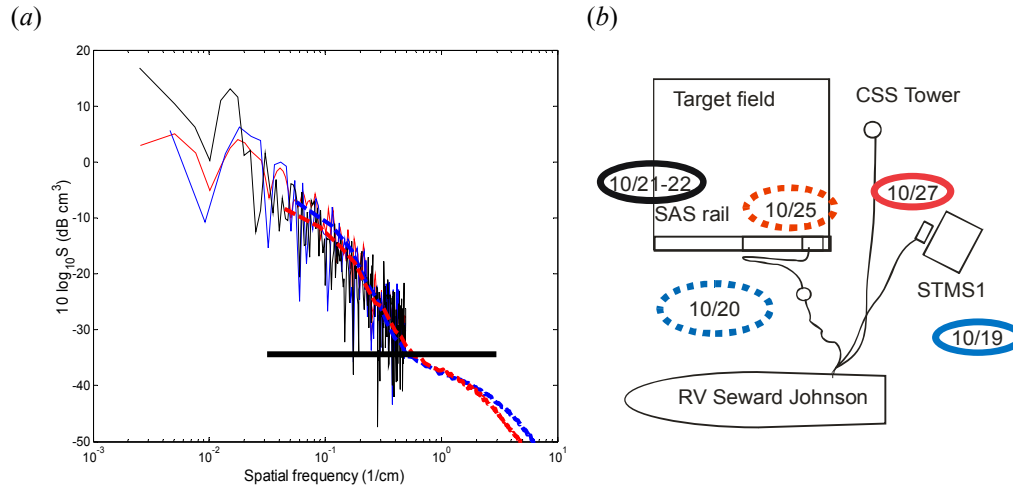


Fig 3: (a) Spectra measured at the SAX04 site using the APL-UW stereo camera system (dashed lines) and the IMP2 measurement system (solid lines). (b) The locations and dates of the roughness measurements taken, the spectra of which are shown in (a).

In the spring of 2005, the stereo system was redeployed in the NSWC-PC test pond following the manual scraping of a ripple onto the sand bottom. The system was deployed to examine the same surface as both IMP2 and the ARL-UT laser scanning system [3]. Some results from preliminary analyses are shown in Fig. 2. This experiment should provide an opportunity to compare the results of all three systems to assess the capabilities and limitations of each.

RESULTS

The spectra measured at two of the locations at the SAX04 site using both the IMP2 system and the APL-UW stereo camera system are shown in Fig. 3a. The locations and time of each measurement are indicated in Fig. 3b. These results show a strong consistency between the two measurement systems. They also indicate that over a period of eight days during the experiment, surface roughness statistics change very little. Likewise, the statistics are similar over a large area of the site.

The roughness spectra measured by the stereo camera system exhibit power-law frequency dependence with a slope of 3.125 for the locations north of the APL-UW rail and 3.71 in the target field. Both of the slopes are steeper than those measured during the Sediment Acoustics Experiment 1999 (SAX99) and do not exhibit the spectral break that was observed during SAX99. However the spectral break found during SAX99 occurred at roughly -35 dB cm^3 which corresponds to the noise floor of the APL-UW stereo camera system (this is indicated by the solid horizontal line in Fig. 3a). This noise floor is poorly understood at present and may have obscured the presence of a spectral break.

IMPACT/APPLICATIONS

The APL-UW stereo camera system has been developed to be an effective and accurate tool for the measurement of seafloor roughness at SAX04 and for future experiments. This is indicated by the consistency with IMP2 which uses an entirely different measurement technique. The performance of

the system was evaluated by the use of a test surface with a known roughness spectrum. This evaluation technique is being adopted by several other groups to assess the performance of other roughness measurement systems.

RELATED PROJECTS

1. Title: High-Frequency Sound Interaction in ocean sediments, Grant# N00014-98-1-0040, E.I. Thorsos, PI. <http://www.apl.washington.edu/projects/SAX04/summary.html> The efforts of SAX04 were coordinated under this program. Among the systems developed and deployed under this project was the SAS rail system for which the APL-UW stereo camera system provided roughness spectra for analysis of sediment backscatter data.

1. Title: Measurement of seabed roughness, Grant# N00014-02-1-0008, D. Tang, PI. APL-UW deployed a bottom-mounted conductivity measurement system (IMP-2) under this program to measure interface roughness at the SAX04 site and at the NSWC-PC test pond. Efforts have been made to coordinate the measurements made using this system with the measurements made using the APL-UW stereo camera system.

REFERENCES

1. E.I. Thorsos, K.L. Williams, D. Tang, and S.G. Kargl, "Sound interaction in ocean sediments," Proceedings of the 1st International Conference on Underwater Acoustic Measurements: Technologies and Results, 28 June – 1 July 2005, Heraklion, Greece.
2. D. Tang, "Fine-scale measurements of sediment roughness and subbottom variability," IEEE J. Oceanic Eng., **29**, 929-939 (2004).
3. M. Isakson, T. Hay, and M. Guild, "A laser light line scan method for determining local interface roughness of the ocean floor," Proceedings of the 1st International Conference on Underwater Acoustic Measurements: Technologies and Results, 28 June – 1 July 2005, Heraklion, Greece.

PUBLICATIONS

B.T. Hefner and C.D. Jones, "Bottom roughness measurements from SAX04: Results from a high-resolution diver-deployed stereo imaging system," Proceedings of Boundary Influences in high frequency, shallow water acoustics, 5-9 September 2005, Bath, UK.